Technical Report 1699
May 1995

Relative Spectral Responsitivity of Two AGEMA Infrared Scanning Cameras

Models 900 SW/ST and 900 LW/ST

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ADMINISTRATIVE INFORMATION

The work detailed in this report was performed by the Naval Command, Control and Ocean Surveillance Center, RDT&E Division, Tropospheric Branch, Code 543, for the Office of Naval Research, Arlington, Virginia. Funding was provided under program element 0602435N, project number RO35E71 for FY 95.

Released by
R. A. Paulus, Head
Tropospheric Branch

Under authority of
J. H. Richter, Head
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Sciences Division

ACKNOWLEDGMENTS

The author acknowledges the contributions of Keith Bentley, Stephen A. Miller, Miles H. Sweet, Russ Clement, and Robert K. Creber for their assistance and advice during these measurements. These personnel are from the Optical Electronics Branch, Code 555, at NRaD.

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EXECUTIVE SUMMARY

OBJECTIVE

Measure the relative spectral responsivity of two infrared camera systems, Models 900 SW/ST and 900 LW/ST, manufactured by AGEMA Infrared Systems Incorporated, Secaucus, New Jersey.

RESULTS

The relative spectral responsivity was measured. In each system, the responsivity is typical of the material from which the detector is made: indium antimonide (InSb) for the AGEMA Model 900 SW/ST camera, and mercury cadmium telluride (HgCdTe) for the AGEMA Model 900 LW/ST camera.

CONTENTS

Figures

Tables

INTRODUCTION

This report describes the measurement of the relative spectral responsivity of two infrared camera systems, Models 900 SW/ST and 900 LW/ST, manufactured by AGEMA Infrared Systems Incorporated. Since this measurement is a standard NRaD procedure that has been thoroughly described in a previous document (Bentley & Miller, 1992), only those aspects of the measurement and data which pertain to these particular systems will be described.

TEST METHODS AND RESULTS

DEFINITIONS

The *response* of a detector, focal plane array, or imaging system is defined as the change δV in its electrical output caused by a change $\delta\Phi$ in the flux onto the responsive surface. The *responsivity* R of a detector is defined as the ratio of its response to the causative change in flux:

$$R \equiv \delta V / \delta\Phi \, . \tag{1}$$

The *spectral responsivity* $R(\lambda)$ of a detector is defined as its responsivity measured with (essentially) monochromatic flux at wavelength λ. The *relative spectral responsivity* $r(\lambda)$ of a detector is defined as the (dimensionless) ratio of the spectral responsivity at wavelength λ to the spectral responsivity at λ_{peak}, the wavelength at which the spectral responsivity has its maximum value:

$$r(\lambda) \equiv R(\lambda)/R(\lambda_{peak}) \, . \tag{2}$$

MEASUREMENT METHOD

The relative spectral responsivity $r_{det}(\lambda)$ of a detector, focal plane array, or imaging system at wavelength λ (microns) is given by

$$r_{\mathrm{det}}(\lambda) = \frac{V_{\mathrm{det}}(\lambda) \cdot r_{ref}(\lambda)/V_{ref}(\lambda)}{\left[V_{\mathrm{det}}(\lambda) \cdot r_{ref}(\lambda)/V_{ref}(\lambda)\right]_{peak}} \, . \tag{3}$$

In this equation, $V_{det}(\lambda)$ and $V_{ref}(\lambda)$ are the electrical responses (volts) of the detector under test and a reference detector, respectively; $r_{ref}(\lambda)$ is the relative spectral responsivity of the reference detector, and *peak* means that the quantity within brackets is to be evaluated at that wavelength for which it is a maximum. The derivation of this equation and the details of the measurement technique have been given in a previous publication (Bentley & Miller, 1992).

THE AGEMA, MODEL 900, SW/ST RESPONSIVITY MEASUREMENT

The relative spectral responsivity of an AGEMA, Model 900, SW/ST camera, Serial Number 963004, with 5- by10-degree lens, Serial Number 01284, was measured. This camera has an indium antimonide (InSb) detector, and it responds in the short- and mid-wave regions of the infrared spectrum.

The camera was mounted horizontally in direct view of the 0.50-mm exit slit of a potassium bromide (KBr), double prism monochromator. The optical path from the exit slit to the front surface of the lens was adjusted to be within ± 1 cm of the 66-cm optical path from the exit slit to the reference detector. Since the camera lens is not capable of bringing objects that are closer than 1 m into clear focus, the lens was set to its minimum focusing distance (approximately 1 m) to concentrate the slit radiation in the image plane for maximum signal as much as possible. The blurred image of the exit slit thus produced is shown in figure 1.

Figure 1. Image of the 0.50-mm exit of the KBr monochromator as seen by the AGEMA, Model 900, SW/ST camera. The window in the upper left-hand corner, labeled “IR-1,” shows a single frame of the image. The window in the lower left-hand corner, labeled “IR-2,” shows an average of the previous 480 frames of the image. The monochromator drum is set to 3 microns, and the slit is out of focus.

Although each pixel in the camera image is calibrated in units of equivalent black-body temperature, for the purposes of this measurement, temperature units were not used. Instead, signal readings were recorded in units that vary from 0 to 8191 (13 bits). They are proportional to the detector output, which is corrected (by internal software) for the influence of the atmosphere between the source and the camera lens. The atmospheric correction is controlled by a file of multiplicative parameters. All parameters in the correction file were set to unity to make the system reading directly proportional to the detector response. (The influence of the atmosphere is removed by the measurement technique itself). An image area (AR01 in figure 1) within the exit slit blur was selected with the system software, and the spatial average of the signal within this area was displayed. This spatially averaged reading was time-averaged for 32 seconds (480 consecutive frames) with the system software. The averaged signal (STAT Avg in figure 1) was recorded by hand after waiting 1 minute to let the signal settle.

Figure 2 shows readings for the AGEMA, Model 900, SW/ST camera system at various wavelengths of the (essentially) monochromatic flux leaving the monochromator. The noise in these data are 0.3-system reading, measured by calculating one standard deviation in 20 nominally constant

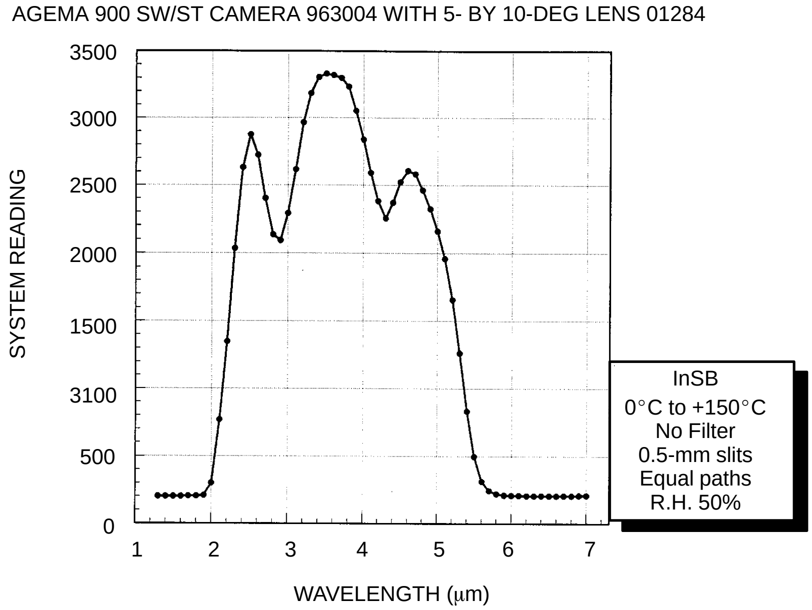

Figure 2. Raw data as a function of wavelength for the AGEMA, Model 900, SW/ST camera system.

readings, each of which was space- and time-averaged as described above. An interesting feature of figure 2 is the constant reading of about 200 at wavelengths below about 1.7 microns and above about 5.5 microns.

An image that is recorded on the system with the monochromator wavelength set to 7.0 microns is shown in figure 3. (Note that the color palette has been readjusted to cover a much smaller range of system readings in figure 3 than that of the range covered in figure 1 by the same color palette.) Since InSb does not respond to radiation at 7.0 microns (refer to table A1 in the appendix), figure 3 cannot be an image of the source; instead, we interpret figure 3 to be a polychromatic image of the *warm* interior of the monochromator. The interior of the monocromator is kept *warm*, slightly above room temperature, to keep moisture from condensing on the prisms.

The system response to radiation sources, apart from the true source (a Nernst glower), is called the "background." In general, the background varies with wavelength because of variations in the monochromator interior as the wavelength is scanned. (For example, there may be internal reflections which change as the mechanical orientation of the prisms changes during the scan.) Normally, the background is automatically removed by mechanically chopping the radiation at a point between the Nernst glower and the entrance slit to the monochromator and by measuring the detector response with a lock-in amplifier. Chopping could not be used with the AGEMA camera because the detector signal was not readily available in electrical form and there was no simple method for synchronizing the camera signal with the chopper. For the AGEMA, Model 900, SW/ST camera, the assumption was made that the background varied linearly with wavelengths between 200.3 (its value at 1.3 microns) and 206.3 (its value at 7.0 microns). This background, $B(\lambda)$, was subtracted from the response, $A(\lambda)$, shown in figure 3, to arrive at the detector voltage, $V_{det}(\lambda)$, used in equation (1) as follows:

$$V_{\mathrm{det}}(\lambda) = C \cdot [A(\lambda) - B(\lambda)] . \tag{4}$$

Figure 3. Image of the 0.5-mm exit of the KBr monochromator as seen by the AGEMA, Model 900, SW/ST camera. The monochromator drum is set to 7 microns, and the slit is out of focus.

In equation (4), *C* is an unknown constant which converts the system reading to voltage and cancels out of equation (3); $A(\lambda)$ is the response shown in figure 2; and $B(\lambda)$ is the background subtracted from this response.

Figure 4 shows the response, $V_{ref}(\lambda)$, of the reference detector, which is a Reeder thermocouple. The thermocouple signal was mechanically chopped at the entrance slit of the monochromator and measured with a Princeton Applied Research, Model 5210, Lock-In amplifier, under the control of a computer. The thermocouple noise was estimated to be 100 nV. The two curves shown in figure 4 were measured immediately before and immediately after the camera data of figure 2 were taken. The difference between them is probably caused by a spatial shift in the pattern of radiation falling on the thermocouple window due to mechanical instabilities in the flat mirror that was used to redirect flux from the camera to the thermocouple. The average of the “before” and “after” reference responses was used for $V_{ref}(\lambda)$ in equation (3).

Figure 5 shows the responsivity (%) of the reference detector measured with respect to the NRaD Primary Standard of Relative Spectral Responsivity more fully described in Bentley and Miller (1992).

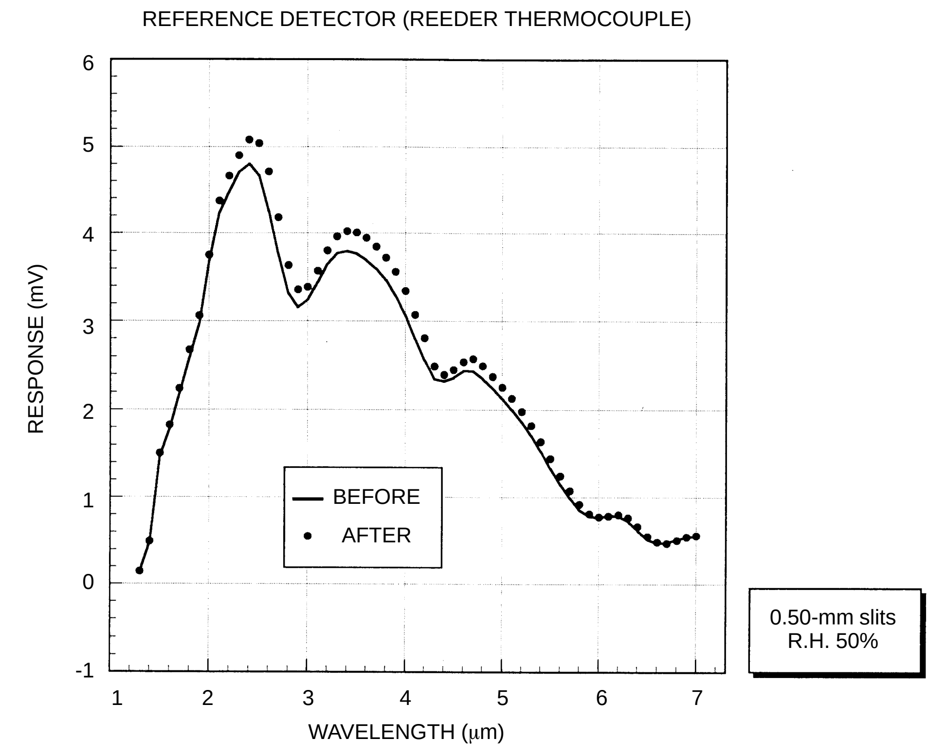

Figure 4. Thermocouple response before and after the data of figure 2 were taken.

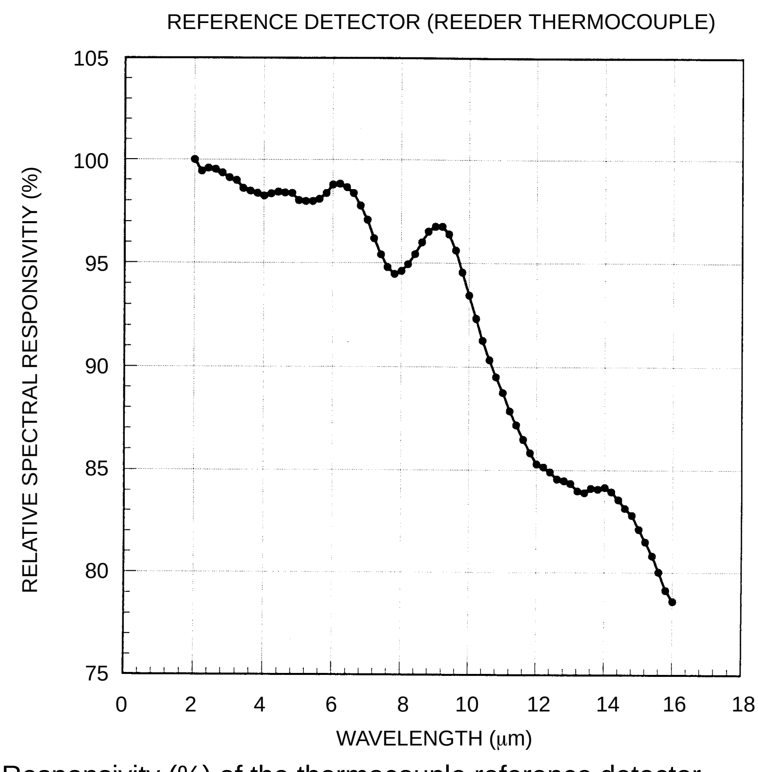

Figure 5. Responsivity (%) of the thermocouple reference detector.

Figure 6 shows the relative spectral responsivity (%) of the AGEMA, Model 900, SW/ST camera determined by the data of figures 2, 4, and 5, and equations (3) and (4). The horizontal bars labeled "FWHM" in figure 6 give the full width of the triangular monochromator passband at one-half its maximum value. (These FWHM values are for equal entrance and exit slit settings of 0.50 mm.) The data of figure 6 are listed in table A1 of the appendix. The third column of table A1 gives the percentage of uncertainty in these data; the true data are equal to the Responsivity (%) (column 2) ± the Uncertainty (%) (column 3). The Uncertainty (%) is an estimate made by taking the root square sum (square root of the sum of the squares) of (1) the noise in the raw signal reading (0.3 reading), (2) uncertainty in the background due to the combined effects of drift, mechanical backlash in the drum, and the assumption of linearity with wavelength (2 reading), and (3) the noise in the thermocouple (100 nV). Below 1.8 microns and above 6.4 microns, the measured responsivity fluctuated between ± 0.1%. Since this is less than the uncertainty in the responsivity and because negative values of responsivity do not make sense, data in these regions have been equated to zero.

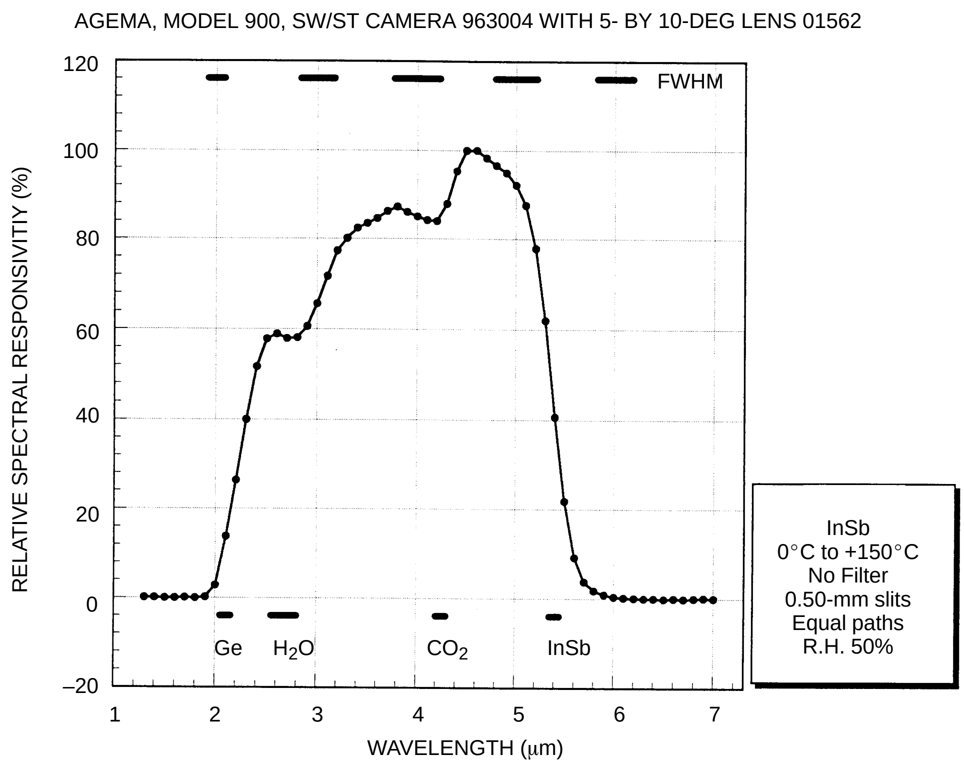

Figure 6. Responsivity of the AGEMA, Model 900, SW/ST camera system. The horizontal bars labeled “FWHM” show the full width at half maximum of the triangular monochromator bandpass for the 0.5-mm entrance and exit slits used in this measurement. The major spectral features of this curve are determined by those materials shown at the bottom of the figure.

THE AGEMA, MODEL 900, LW/ST RESPONSIVITY MEASUREMENT

The relative spectral responsivity of an AGEMA, Model 900, LW/ST camera, Serial Number 973006, with 5- by 10-degree lens, Serial Number 01562, was measured. This camera has a mercury cadmium telluride (HgCdTe) detector and responds in the long-wave region of the infrared spectrum.

To properly remove the influence of the atmosphere from this measurement, the detector, focal plane, or imaging system must be mounted at the same distance from the exit slit as the thermocouple (66 cm); however, in this location the response was weak. The front surface of the camera lens was therefore placed 180 ± 0.5 cm from the exit slit where the lens could be adjusted to bring the 0.50-mm slit into focus. When focused, the image of the exit slit was less than 1-pixel wide, producing a stronger reading of about 3100 at a wavelength of 8 microns near the peak of this camera’s response; however, at sharp focus, there was also a large amount of noise perhaps due to jitter shifting the image out of the pixel. The lens was therefore defocused until a blurred image was produced that gave the best signal-to-noise ratio. An area near the center of this optimum blur was chosen for spatial and temporal (32 seconds) averaging. With optimum blur, the 8-micron response was a reading of about 2200, and the noise was about ± 0.5. The use of unequal paths introduces a systematic error into this measurement in those spectral regions where atmospheric absorption is strong. This error has not been estimated, but the final paragraph of this report alerts the reader to its location. Other than the use of unequal paths, the measurement method and analysis were the same as those previously described for the AGEMA, Model 900, SW/ST camera.

The raw response of the AGEMA, Model 900, LW/ST is shown in figure 7. The background readings were 1891.5 at 4 microns and 1898.0 at 15 microns with a combined uncertainty estimated to be ± 2 reading due to noise, drift, and backlash. A linear interpolation between 4 and 15 microns was used for *B(*

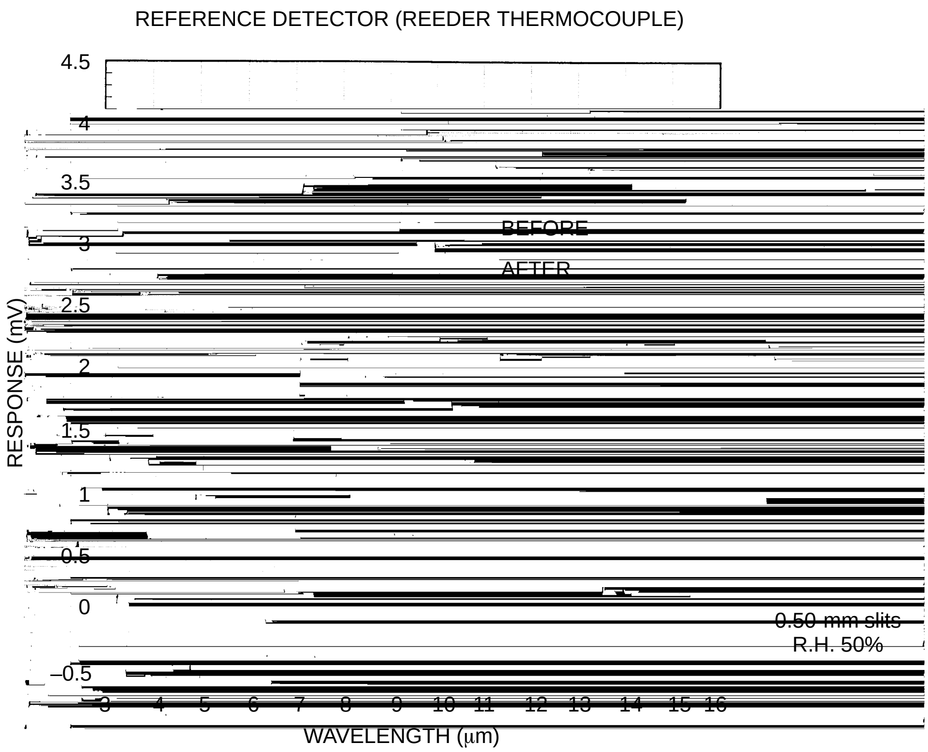

Figure 8. Thermocouple response before and after the data of figure 7 were taken.

The relative spectral responsivity of the AGEMA, Model 900, LW/ST camera, determined by the data of figures 5, 7, and 8, and equations (3) and (4), is shown in figure 9. Numerical values and their uncertainty are given in table A2 of the appendix. The data at 13.4 microns and above have been replaced with data which fall smoothly to zero within the uncertainty envelope. The original data are shown by open circles in figure 9.

The long-wave camera system has a filter that can be removed or placed in the optical path. (The long-wave measurements just described were made without this filter.) The long-wave measurements were repeated with the filter in the path; however, the filter was first removed from the camera, and its transmission was measured separately. This was done by forming the ratio at each wavelength of thermocouple voltages with and without the filter over the exit slit. The transmission (%) is shown in figure 10, and data are listed in table A3 of the appendix. The filter is a long pass with a transmission edge at 7.5 microns.

The raw response of the AGEMA, Model 900, LW/ST camera with the filter installed is shown in figure 11. The noise reading was about ± 0.5. Starting at 6 microns, the background was measured every 0.5 micron by manually placing an opaque blade between the Nernst glower and the entrance slit of the monochromator. The 0.5-micron intervals between background measurements were filled in by linear interpolation. The combined uncertainty in the background reading (due to noise, drift, and backlash) was estimated to be ± 1.5 reading.

The thermocouple response was measured before and after the data of figure 11 were taken, and the results, which are not shown, were similar to those shown in figure 8.

Figure 12 and the appendix table A4 give the relative spectral responsivity of the AGEMA, Model 900, LW/ST camera with the long-pass filter.

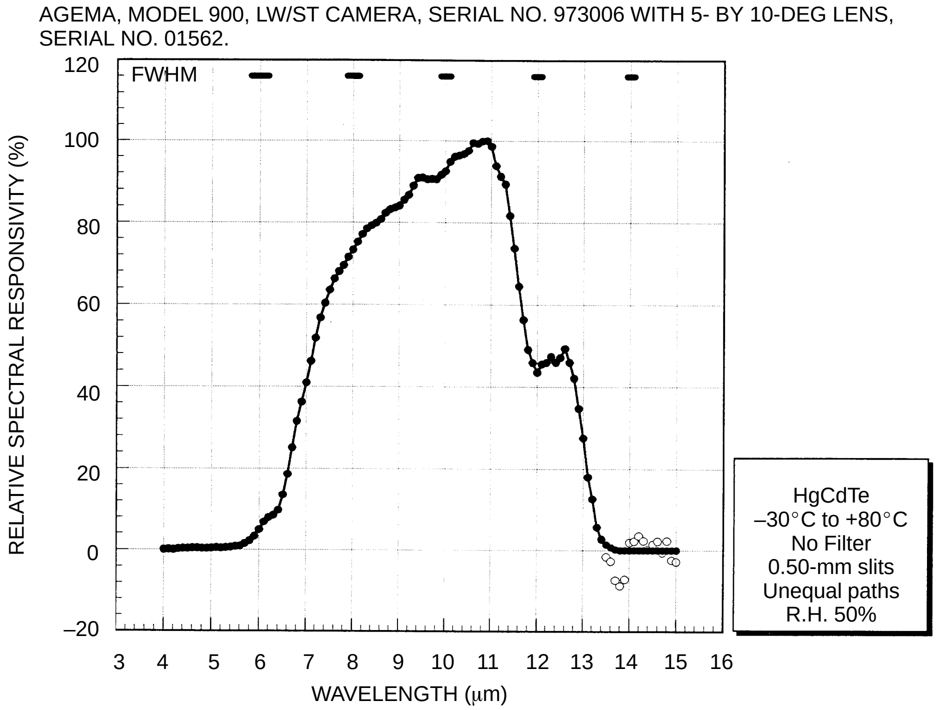

Figure 9. Responsivity of the AGEMA, Model 900, LW/ST camera system with no filter in the optical path. The data shown as solid circles are listed in table A2. From 13.4 to 15.0 μm, the open circles are measured data and the closed circles are recommended data.

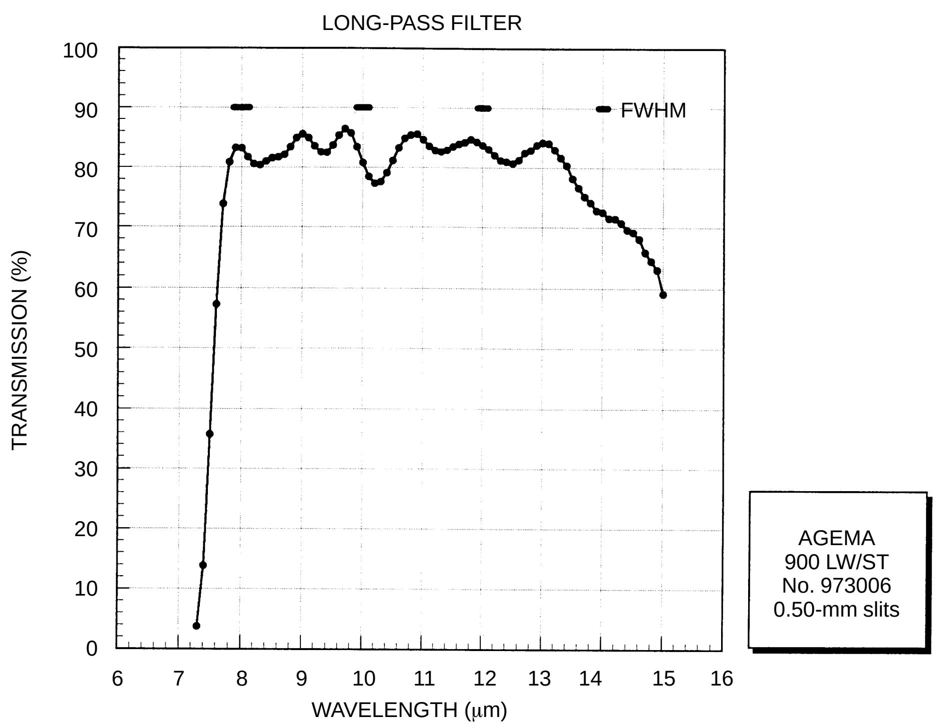

Figure 10. Transmission (%) of the AGEMA, Model 900, LW/ST filter. These data are also given in table A3.

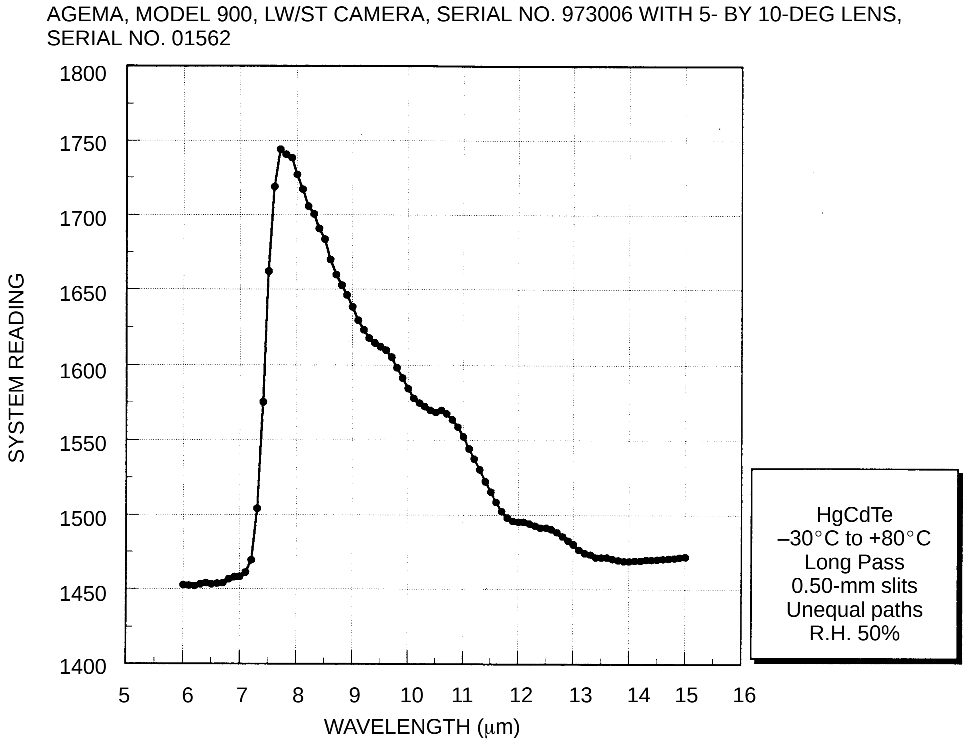

Figure 11. Raw data as a function of wavelength for the AGEMA, Model 900, LW/ST camera

measurement (figure 9). This comparison is shown in figure 13 after renormalization. The agreement is satisfactory.

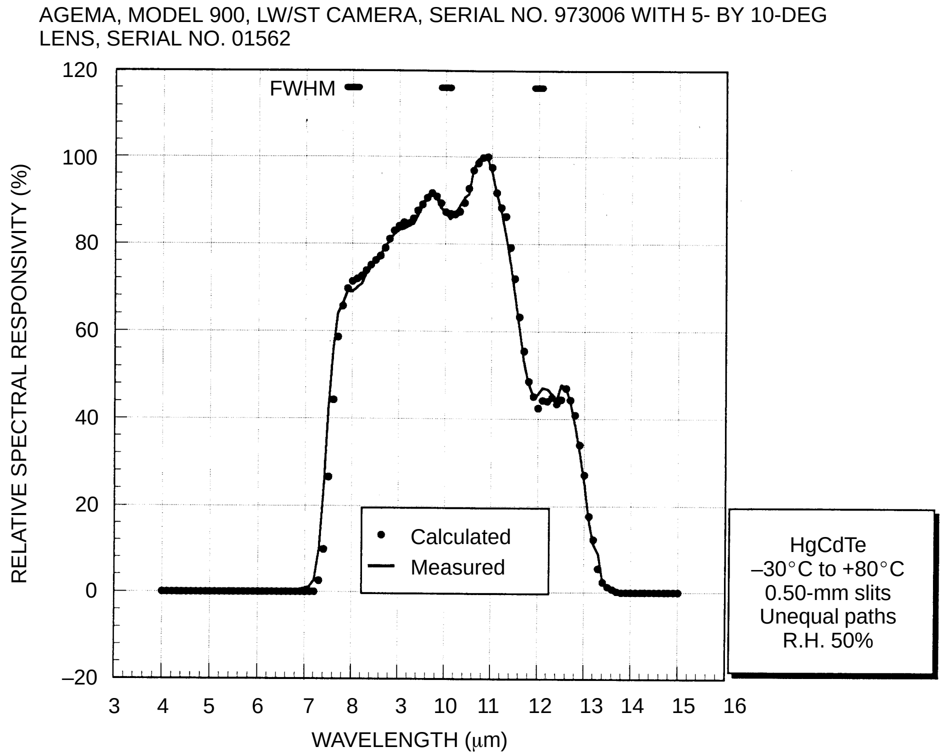

Figure 13. Comparisons of long-wave data. The solid line repeats the responsivity data of figure 12 (filter in). The solid circles are calculated from the normalized product of the filter transmission (figure 10) and the responsivity data of figure 9 (filter out).

CONCLUSIONS

DISCUSSION OF AGEMA CAMERA RELATIVE SPECTRAL RESPONSIVITIES

The responsivity of each of these cameras is typical of a photon detector. For an ideal photon detector (Hudson, 1969), the relative responsivity is proportional to wavelength up to a cutoff determined by the band gap of the detector material. Put another way, the responsivity of an ideal photon detector is 50 percent at a wavelength equal to one-half the cutoff wavelength. Optical characteristics of lenses and filters can cause a deviation from ideal behavior; for example, the responsivity at a given wavelength can be increased by anti-reflection coatings. The responsivity of these cameras obey the ideal characteristics only approximately.

The long wavelength cutoff of each camera is set by the band gap of each detector material. At the bottom of figure 6, the horizontal bar labeled “InSb” shows the low-temperature, energy gap of indium antimonide (CRC Press, 1988–89), which agrees well with the maximum wavelength of responsivity. The band gap of the HgCdTe detector depends on the composition of the alloy, which is not known. We interpret the fall in long-wave responsivity, at wavelengths between 11 and 12 microns, to be due to the band gap of the HgCdTe, and the 50-percent peak, between 12 and 13 microns, to be due to an impurity within the gap.

At the bottom of figure 6, the remaining horizontal bars (labeled Ge, H_2O, and CO_2, respectively) show the transmission edge of a 1-mm sample of germanium (The Infrared and Information Analysis

Center, 1993) and atmospheric absorption lines due to water and carbon dioxide. The short wavelength edge of the responsivity in figure 6 is consistent with the use of Ge as a lens material. The atmospheric absorption data were obtained from a LOWTRAN calculation (Kneizys et al., 1988) of the transmission for a 1-m path through a U. S. Standard Atmosphere with 50-percent relative humidity. The results of this calculation are shown in figure 14. We interpret the two dips in camera responsivity at 2.7 μm and 4.3 μm as absorption along the atmospheric path between the front lens and the InSb detector inside the AGEMA, Model 900, SW/ST camera.

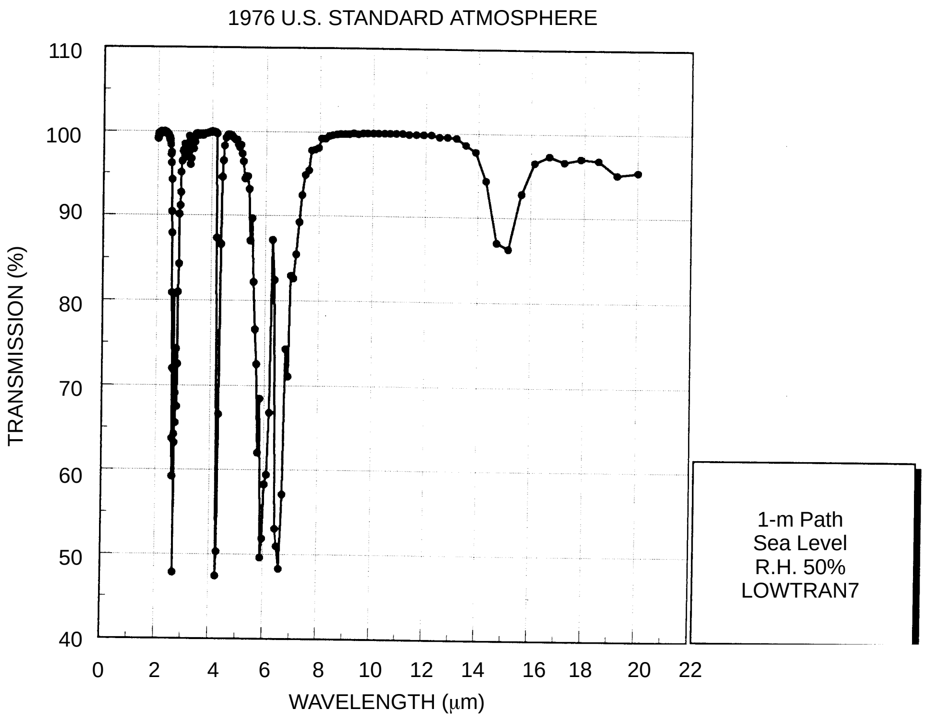

Figure 14. 1976 standard atmospheric transmission of a 1-m sea level path for a relative humidity of 50 percent.

Because the paths from exit slit to thermocouple and lens were unequal in the long-wave measurement, a systematic error was introduced, thereby calling into question the accuracy of that measurement at about 5.9 microns and about 6.7 microns at the minima shown in figure 14. The data at wavelengths below 7 microns, shown in figure 9 and appendix table A2, should therefore be viewed with caution.

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APPENDIX A

TABLES

Table A1. AGEMA, Model 900, SW/ST, Serial No. 963004 with 5- by 10-deg lens, Serial Number 01284, InSb detector, 0° to +150°C range, no filters, KBr prism monochromator with 0.50-mm slits, equal paths to thermocouple and front lens surface, 15 February 1995, Run B.

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
1.3	0.0	1.7
1.4	0.0	0.5
1.5	0.0	0.2
1.6	0.0	0.1
1.7	0.0	0.1
1.8	0.0	0.1
1.9	0.2	0.1
2.0	2.8	0.1
2.1	13.8	0.1
2.2	26.3	0.1
2.3	40.0	0.1
2.4	51.6	0.0
2.5	57.8	0.1
2.6	58.9	0.1
2.7	57.9	0.1
2.8	58.1	0.1
2.9	60.6	0.1
3.0	65.7	0.1
3.1	71.7	0.1
3.2	77.3	0.1
3.3	80.1	0.1
3.4	82.4	0.1
3.5	83.5	0.1
3.6	86.2	0.1
3.7	87.2	0.1
3.8	86.0	0.1
3.9		
4.0	85.0	0.1
4.1	84.2	0.1
4.2	84.0	0.1
4.3	87.9	0.1
4.4	95.3	0.1
4.5	100.0	0.1
4.6	100.0	0.1
4.7	98.3	0.1
4.8	96.6	0.1
4.9	94.9	0.1
5.0	92.1	0.1
5.1	87.6	0.1
5.2	77.9	0.1
5.3	62.0	0.1
5.4	40.7	0.2
5.5	21.8	0.2
5.6	9.2	0.2
5.7	3.7	0.2
5.8	1.7	0.3
5.9	0.8	0.3

Table A1. AGEMA, Model 900, SW/ST, Serial No. 963004 with 5- by 10-deg lens, Serial Number 01284, InSb detector, 0° to +150°C range, no filters, KBr prism monochromator with 0.50-mm slits, equal paths to thermocouple and front lens surface, 15 February 1995, Run B. (Continued)

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
6.0	0.4	0.3
6.1	0.2	0.3
6.2	0.1	0.3
6.3	0.0	0.3
6.4	0.0	0.4
6.5	0.0	0.4
6.6	0.0	0.5
6.7	0.0	0.5
6.8	0.0	0.5
6.9	0.0	0.4
7.0	0.0	0.4

Table A2. AGEMA, Model 900, LW/ST, Serial No. 973006 with 5- by 10-deg lens, Serial Number 01562, HgCdTe detector, –30° to +80°C range, no filter, KBr prism monochromator, 0.50-mm slits, unequal paths to TC and front lens surface, 15 March 1995, Run E. At wavelengths of 13.4 μm and above, these are recommended data, not measured data.

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
4.0	0.0	0.1
4.1	0.0	0.1
4.2	0.1	0.1
4.3	0.2	0.1
4.4	0.3	0.1
4.5	0.3	0.1
4.6	0.4	0.1
4.7	0.4	0.1
4.8	0.3	0.1
4.9	0.3	0.1
5.0	0.4	0.1
5.1	0.5	0.1
5.2	0.4	0.1
5.3	0.5	0.1
5.4	0.6	0.2
5.5	0.8	0.2
5.6	0.9	0.2
5.7	1.5	0.2
5.8	2.2	0.3
5.9	3.3	0.3
6.0	4.9	0.3
6.1	6.8	0.3
6.2	7.9	0.3
6.3	8.5	0.3
6.4	9.7	0.4
6.5	13.5	0.5
6.6	18.6	0.5
6.7	25.1	0.6
6.8	31.5	0.5
6.9	36.2	0.5
7.0	40.9	0.5
7.1	46.2	0.5
7.2	51.9	0.5
7.3	56.8	0.5
7.4	60.3	0.5
7.5	63.5	0.5
7.6	66.2	0.5
7.7	68.0	0.5
7.8	69.5	0.5
7.9	71.5	0.5

Table A2. AGEMA, Model 900, LW/ST, Serial No. 973006 with 5- by 10-deg lens, Serial Number 01562, HgCdTe detector, –30° to +80°C range, no filter, KBr prism monochromator, 0.50-mm slits, unequal paths to TC and front lens surface, 15 March 1995, Run E. At wavelengths of 13.4 μm and above, these are recommended data, not measured data. (Continued)

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
8.0	73.3	0.6
8.1	75.2	0.6
8.2	77.1	0.6
8.3	78.5	0.7
8.4	79.3	0.7
8.5	79.9	0.8
8.6	80.8	0.8
8.7	82.3	0.9
8.8	83.2	0.9
8.9	83.6	1.0
9.0	84.1	1.0
9.1	85.5	1.1
9.2	86.7	1.2
9.3	88.9	1.2
9.4	90.8	1.3
9.5	90.9	1.3
9.6	90.5	1.4
9.7	90.6	1.4
9.8	90.5	1.5
9.9	91.6	1.6
10.0	92.5	1.6
10.1	94.8	1.7
10.2	96.1	1.8
10.3	96.4	1.8
10.4	96.8	1.9
10.5	97.6	2.0
10.6	99.5	2.1
10.7	99.3	2.2
10.8	99.9	2.3
10.9	100.0	2.4
11.0	98.6	2.5
11.1	93.8	2.6
11.2	91.2	2.7
11.3	89.3	2.8
11.4	81.7	2.9
11.5	73.7	3.1
11.6	64.5	3.2
11.7	56.4	3.3
11.8	49.1	3.4
11.9	45.9	3.5

Table A2. AGEMA, Model 900, LW/ST, Serial No. 973006 with 5- by 10-deg lens, Serial Number 01562, HgCdTe detector, –30° to +80°C range, no filter, KBr prism monochromator, 0.50-mm slits, unequal paths to TC and front lens surface, 15 March 1995, Run E. At wavelengths of 13.4 μm and above, these are recommended data, not measured data. (Continued)

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
12.0	43.5	3.6
12.1	45.6	3.8
12.2	46.0	3.9
12.3	47.4	4.1
12.4	46.0	4.3
12.5	47.2	4.5
12.6	49.4	4.6
12.7	46.0	4.8
12.8	42.1	5.0
12.9	34.7	5.2
13.0	27.5	5.4
13.1	18.0	5.7
13.2	12.6	5.9
13.3	5.6	6.1
13.4	2.5	6.4
13.5	1.3	6.6
13.6	0.7	6.9
13.7	0.2	7.2
13.8	0.0	7.5
13.9	0.0	7.9
14.0	0.0	8.2
14.1	0.0	8.6
14.2	0.0	9.0
14.3	0.0	9.6
14.4	0.0	10.4
14.5	0.0	11.5
14.6	0.0	12.4
14.7	0.0	13.2
14.8	0.0	13.8
14.9	0.0	17.4
15.0	0.0	17.2

Table A3. AGEMA, Model 900, LW/ST, long-pass filter transmission, serial no. 973006, KBr prism monochromator with 0.50-mm slits, 14 March 1995, Run D.

Wavelength (microns)	Transmission (%)
7.3	3.8
7.4	13.8
7.5	35.7
7.6	57.3
7.7	73.8
7.8	80.9
7.9	83.3
8.0	83.2
8.1	81.8
8.2	80.6
8.3	80.4
8.4	81.0
8.5	81.6
8.6	81.8
8.7	82.2
8.8	83.4
8.9	84.9
9.0	85.6
9.1	84.9
9.2	83.6
9.3	82.6
9.4	82.5
9.5	83.7
9.6	85.4
9.7	86.4
9.8	85.7
9.9	83.5
10.0	80.8
10.1	78.5
10.2	77.3
10.3	77.6
10.4	79.1
10.5	81.2
10.6	83.3
10.7	84.9
10.8	85.4
10.9	85.6
11.0	84.6
11.1	83.6
11.2	82.9
11.3	82.7
11.4	82.9
11.5	83.5
11.6	84.0
11.7	84.2
11.8	84.7
11.9	84.3

Table A3. AGEMA, Model 900, LW/ST, long-pass filter transmission, serial no. 973006, KBr prism monochromator with 0.50-mm slits, 14 March 1995, Run D. (Continued)

Wavelength (microns)	Transmission (%)
12.0	83.7
12.1	83.1
12.2	82.1
12.3	81.2
12.4	81.0
12.5	80.8
12.6	81.3
12.7	82.5
12.8	83.0
12.9	83.8
13.0	84.2
13.1	84.1
13.2	83.0
13.3	81.7
13.4	80.4
13.5	78.2
13.6	76.6
13.7	75.1
13.8	74.1
13.9	72.8
14.0	72.5
14.1	71.5
14.2	71.4
14.3	70.7
14.4	69.6
14.5	69.1
14.6	68.1
14.7	65.8
14.8	64.4
14.9	63.0
15.0	59.1

Table A4. AGEMA, Model 900, LW/ST, serial no. 973006 with 5- by 10-deg lens, serial no. 01562, HgCdTe detector, –30°C to +80°C range, long-pass filter, KBr prism monochromator, 0.50-mm slits, unequal paths to TC and front lens surface, 15 March 1995, Run E. At wavelengths of 13.4 μm and above, these are recommended data, not measured data.

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
6.0	0.0	0.3
6.1	0.0	0.3
6.2	0.0	0.3
6.3	0.0	0.3
6.4	0.0	0.4
6.5	0.0	0.4
6.6	0.0	0.5
6.7	0.0	0.4
6.8	0.4	0.4
6.9	0.6	0.4
7.0	0.8	0.4
7.1	1.2	0.4
7.2	2.7	0.4
7.3	9.6	0.4
7.4	24.1	0.4
7.5	43.1	0.4
7.6	56.5	0.4
7.7	64.1	0.5
7.8	66.4	0.5
7.9	69.0	0.5
8.0	68.9	0.5
8.1	69.9	0.6
8.2	70.8	0.6
8.3	73.1	0.6
8.4	74.6	0.7
8.5	76.3	0.7
8.6	77.5	0.8
8.7	79.2	0.8
8.8	80.9	0.9
8.9	82.3	0.9
9.0	83.2	1.0
9.1	83.4	1.0
9.2	84.1	1.1
9.3	84.6	1.1
9.4	86.5	1.2
9.5	88.7	1.2
9.6	91.0	1.3
9.7	91.4	1.3
9.8	90.3	1.4
9.9	88.2	1.4

Table A4. AGEMA, Model 900, LW/ST, serial no. 973006 with 5- by 10-deg lens, serial no. 01562, HgCdTe detector, –30°C to +80°C range, long-pass filter, KBr prism monochromator, 0.50-mm slits, unequal paths to TC and front lens surface, 15 March 1995, Run E. At wavelengths of 13.4 μm and above, these are recommended data, not measured data. (Continued)

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
10.0	87.0	1.5
10.1	85.7	1.6
10.2	87.0	1.6
10.3	88.7	1.7
10.4	90.4	1.8
10.5	91.3	1.9
10.6	97.2	1.9
10.7	99.4	2.0
10.8	100.0	2.1
10.9	99.4	2.2
11.0	96.4	2.3
11.1	91.4	2.4
11.2	87.4	2.5
11.3	82.0	2.6
11.4	75.5	2.7
11.5	68.5	2.8
11.6	60.8	2.9
11.7	53.0	3.0
11.8	47.9	3.1
11.9	45.3	3.2
12.0	45.7	3.3
12.1	47.1	3.5
12.2	46.8	3.6
12.3	45.7	3.8
12.4	44.4	3.9
12.5	47.8	4.1
12.6	47.1	4.3
12.7	43.9	4.4
12.8	38.7	4.6
12.9	32.4	4.8
13.0	25.2	5.0
13.1	16.4	5.2
13.2	11.1	5.4
13.3	9.0	5.6
13.4	2.4	5.8
13.5	1.2	6.1
13.6	0.6	6.3
13.7	0.2	6.6
13.8	0.0	6.9
13.9	0.0	7.2

Table A4. AGEMA, Model 900, LW/ST, serial no. 973006 with 5- by 10-deg lens, serial no. 01562, HgCdTe detector, –30°C to +80°C range, long-pass filter, KBr prism monochromator, 0.50-mm slits, unequal paths to TC and front lens surface, 15 March 1995, Run E. At wavelengths of 13.4 μm and above, these are recommended data, not measured data. (Continued)

Wavelength (microns)	Responsivity (%)	Uncertainty (%)
14.0	0.0	7.4
14.1	0.0	7.7
14.2	0.0	8.1
14.3	0.0	8.5
14.4	0.0	9.3
14.5	0.0	10.2
14.6	0.0	11.0
14.7	0.0	11.6
14.8	0.0	12.1
14.9	0.0	15.9
15.0	0.0	13.7

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
May 1995

3. REPORT TYPE AND DATES COVERED
Final: May 1995

4. TITLE AND SUBTITLE
RELATIVE SPECTRAL RESPONSIVITY OF TWO AGEMA INFRARED SCANNING CAMERAS
Models 900 SW/ST and 900 LW/ST

5. FUNDING NUMBERS
ACC: DN302215
PE: 0602435N
PN: RO35E71

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Command, Control and Ocean Surveillance Center (NCCOSC)
RDT&E Division
San Diego, CA 92152–5001

8. PERFORMING ORGANIZATION REPORT NUMBER
TR 1699

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Relative spectral responsivity data are presented for two infrared camera systems, Models 900 SW/ST and 900 LW/ST, manufactured by AGEMA Infrared Systems Incorporated, Secaucus, New Jersey.

14. SUBJECT TERMS
Electrooptics
Propagation
Atmosphere

15. NUMBER OF PAGES
34

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAME AS REPORT

21a. NAME OF RESPONSIBLE INDIVIDUAL	21b. TELEPHONE *(include Area Code)*	21c. OFFICE SYMBOL
C. R. Zeisse	(619) 553–3602	Code 543